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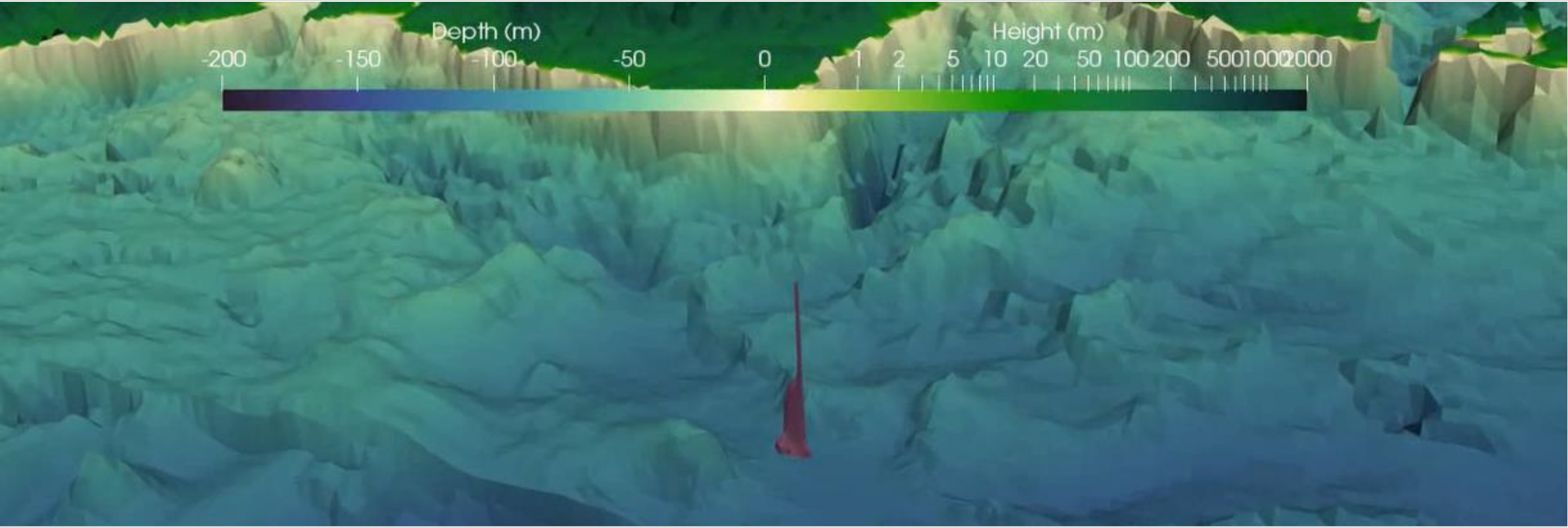
PRE-ACT

Accelerating CCS Technologies



Impact potential of hypersaline brines released into the marine environment as part of reservoir pressure management.

Jerry Blackford, Marius Dewar, Tony Espie, Sarah Wilford, Nicolas Bouffin

Jerry Blackford *:* jcb@pml.ac.uk

- Project Overview

Pressure control and conformance management for safe and Efficient CO_2 storage – Accelerating CCS technologies (Pre-ACT):
https://www.sintef.no/projectweb/pre-act/

ACT is a European Research Area Network (ERA-NET) Cofund supporting collaborative projects to accelerate the deployment of carbon capture, utilisation and storage, CCUS.
http://www.act-ccs.eu/

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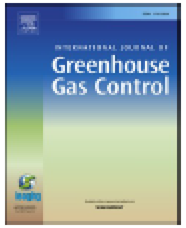

Impact potential of hypersaline brines released into the marine environment for CCS reservoir pressure management

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Reservoir Pressure Management

- Pressure management of reservoirs used for carbon dioxide storage is a key component of maintaining cap rock and reservoir integrity of the storage complex.
- Where storage utilizes **saline aquifers**, pressure management may potentially require production of reservoir brines and their dispersion in over-lying seawater or the expensive re-injection-to a secondary storage facility.
- **Saline aquifers** are a substantial storage resource

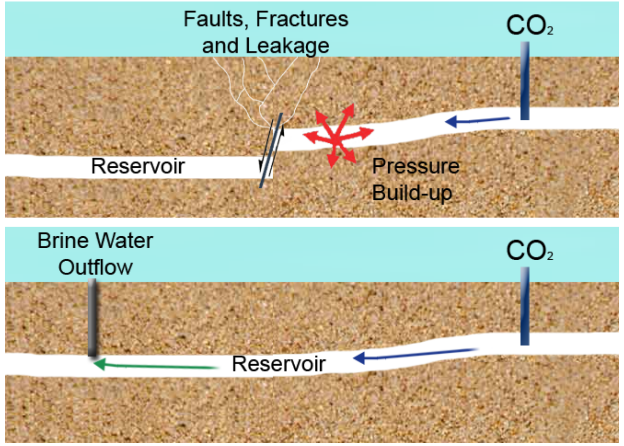


Figure 1. Schematic of the threat from reservoir pressure build-up, with the potential of faults fractures and CO_2 leakage (top); and a suggested solution to manage reservoir pressures (bottom).

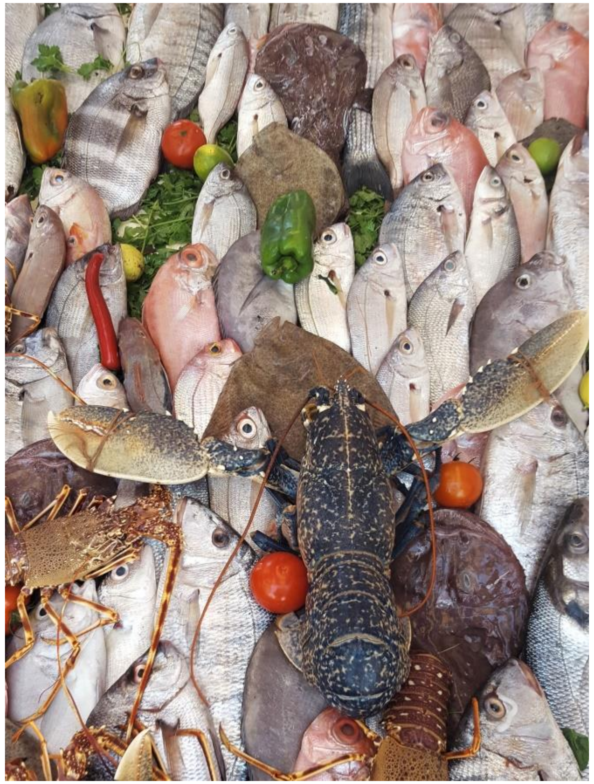
PRE-ACT

- PML's Contribution to Pre-ACT

Assess the impact potential of large-scale disposal of produced reservoir brines into the marine environment:

- Different disposal methods
- Different environmental conditions

We will test the hypothesis that ***"hypersaline discharge will cause a restricted local impact, but in the context of well mixed shelf sea environments (like the North Sea), hydrodynamically driven dispersion and dilution will significantly restrict impact to regional ecosystems".***



Potential Impact: Brine Characteristics

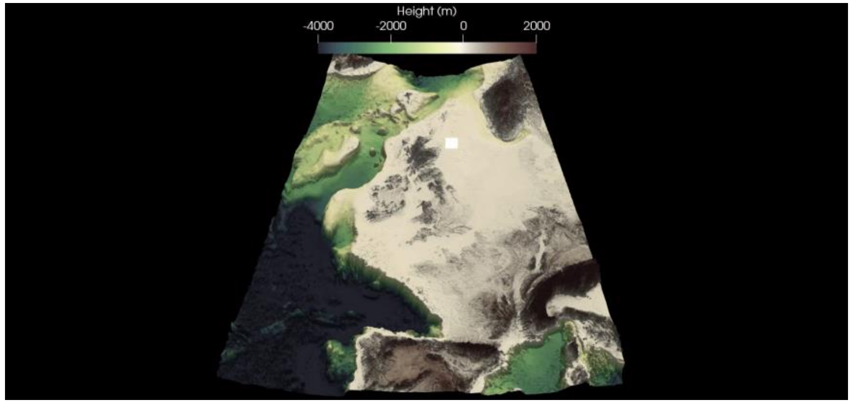
- The characteristics of these brines vary greatly:
  - Hypersaline (exceeding 200 PSU). Normal is ~33-~39 PSU
  - Hot (exceeding 50° C). Normal is -2° to 30° C
  - Anoxic and / or with elevated levels of contaminants.

- Undiluted, such brines may have the potential to be detrimental to ecosystems

The Dead Sea…
> 300 PSU
20-39° C

Methods

- We use a variable mesh hydrodynamic model
  - Utilise the Unstructured Grid, Finite-Volume Coastal Ocean Model (FVCOM)
    - Adapted to simulate sea-surface and seabed brine releases to assess the dispersion of hypersaline brines in the natural environment.
- This model allows for very high resolution in the vicinity of the release point
  - From kilometers at the boundary, down to 5 meters in the vicinity of the discharge.
  - The dynamics and dispersion of plumes can be modelled in detail.



- Lower resolution towards the model boundaries
  - Restricts computational cost.
  - Maintains the ability to accurately simulate the physical mixing process acting on shelf seas.

Methods

- Detailed bathymetry within the North Sea enables the assessment of any impact seafloor morphology may have on dispersal or retention of brines.
  - Sand-waves in sediments generated by the water flow may collect denser high salinity waters
- The model is forced by realistic tidal, current, thermal and wind driven mixing.
- Boundary conditions supplied by reanalysis simulations of the wider area.

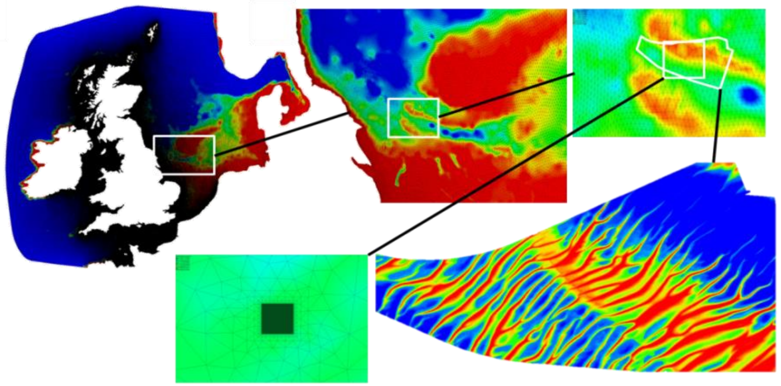
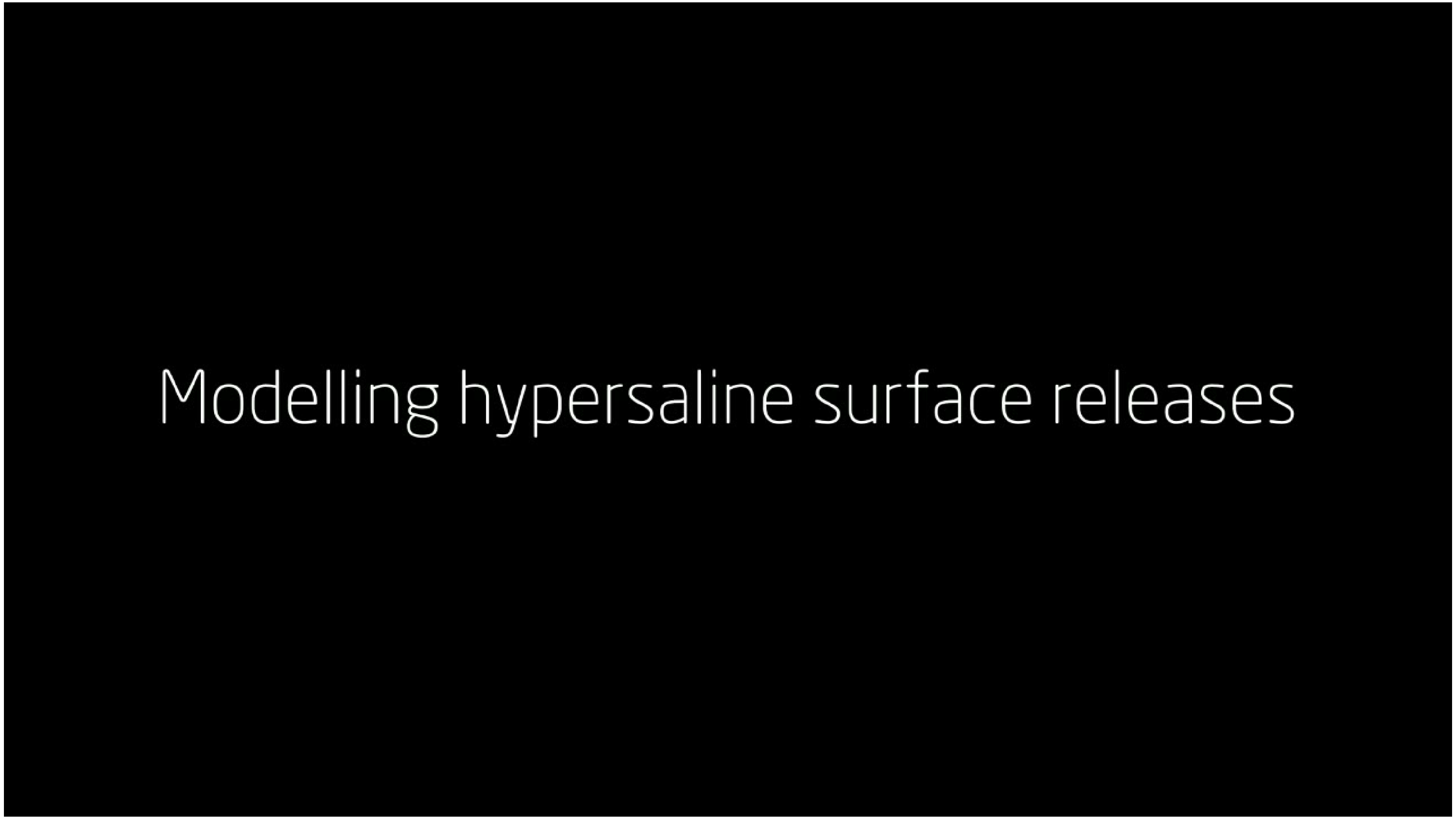


Figure 2. Schematic of the model nesting scheme, clockwise from top left; wide area model domain suppling boundary forcing; intermediate domain showing regional bathymetry features; release simulation domain; applied high resolution bathymetry showing sand waves; ultra-high resolution model center with meter scale resolution.



Surface shows 1 PSU above background

https://www.youtube.com/watch?v=zEiZ7cIP_dI – search “hypersaline” on youtube

Scenarios

Worst case approach – to define the maximum impact potential

40,000 Barrels/day or 2.32 Mt/A deliberately produced brine

- 1 seafloor producer

160,000 Barrels/day or 9.3 Mt/A deliberately produced brine

- 1 sea surface disposal point
- 1 mid depth disposal point

20,000 Barrels/day or 1.2 Mt/A seeped brine from a geological outcrop

- Single point source
- Spread over 10 point sources

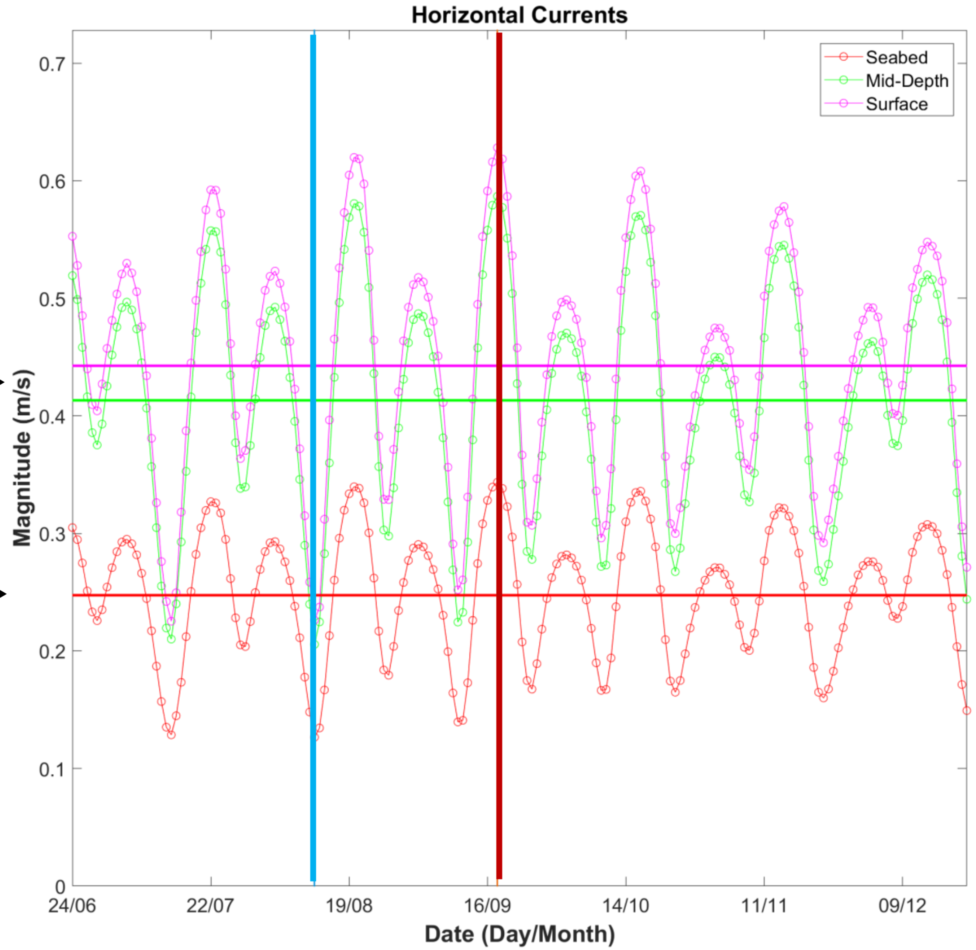
Scenario	Release Rate		Salinity PSU	Temp ° C	Release mode
	Mt/a	barrels/day			
1	2.32	40,000	258	56	Sea floor single producer (of 4)
2	9.29	160,000			Sea surface maximum predicted disposal
3	9.29	160,000			Mid-depth
4	1.16	20,000			Sea floor 1 seep point
5	10 X 0.116	10 x 2,000			Sea floor 10 separate seep points

Analysis

6 month spin up
Continuous results over 6 month period

Presenting snapshots from the period of
- Maximum horizontal currents
- Minimum horizontal currents

Difference in mean current velocity between sea surface and seafloor explain the differences in results between sea surface and seafloor dispersal



Impact Thresholds

	Impact threshold	Based on	Dilution*
Salinity	+ 5% or +1.75PSU	Desalination literature	1:127
Temperature	+ 5 ° C	Typical in-situ temperature ranges	1:9
Oxygen	4.7mg/l	EU Water Framework Directive	1:3
Contaminants†	+ 0.13% +0.045PSU	PNEC	1:5000

†This is a worst case scenario based on an Arsenic concentration of 24mg/l

*Entirely dependent on brine salinity, temperature, degree of anoxia, contaminant concentration and the PNEC (Predicted No Effect Concentration) of the specific contaminant compound.

- Likely that contaminant concentration will be the defining impact
- Impact thresholds can be quite challenging to define

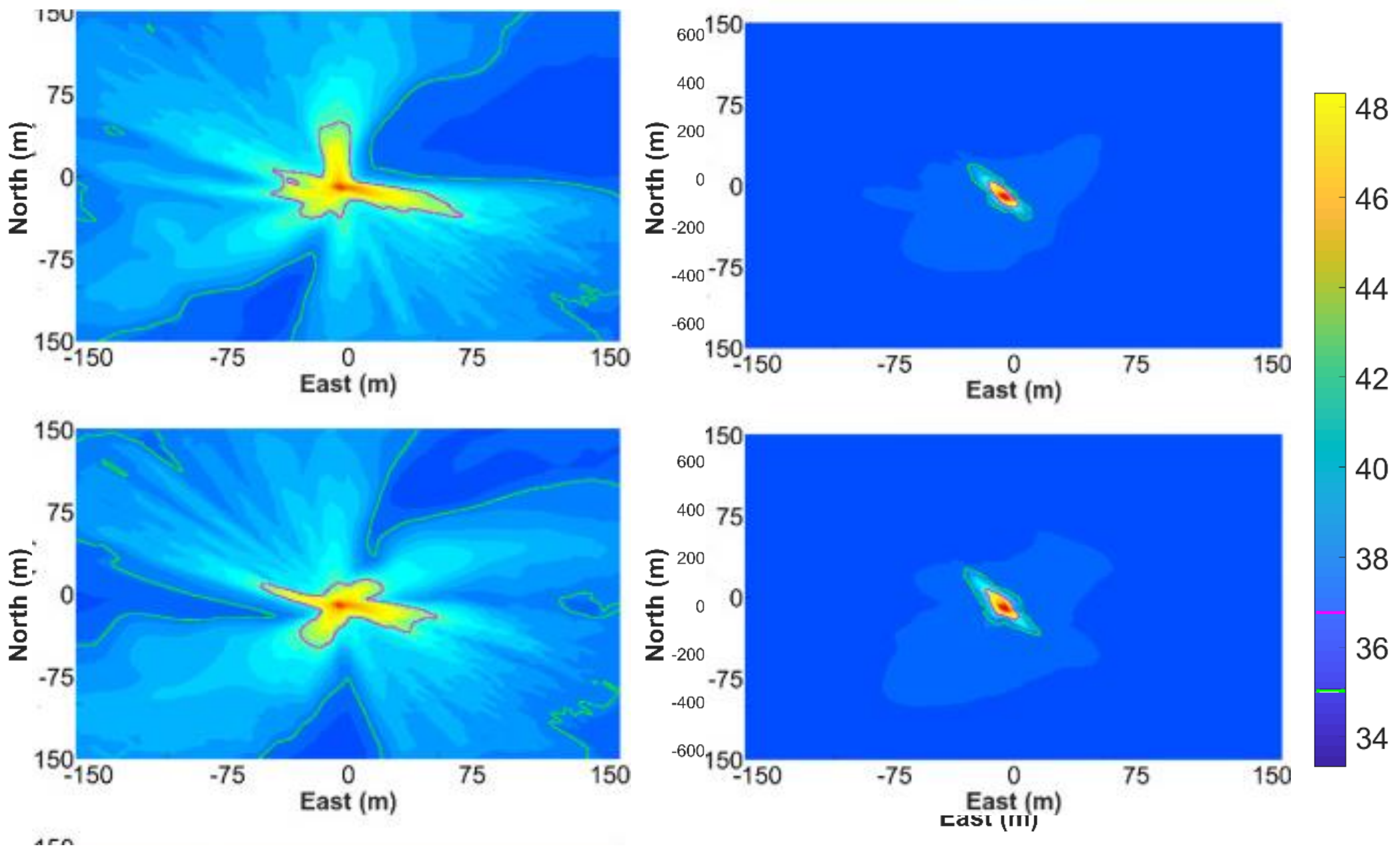
24hr Integrated plume footprint

Seabed release 40,000 b/d

Sea surface release 160,000 b/d

High current

Low current



Little evidence of sea floor morphology effect

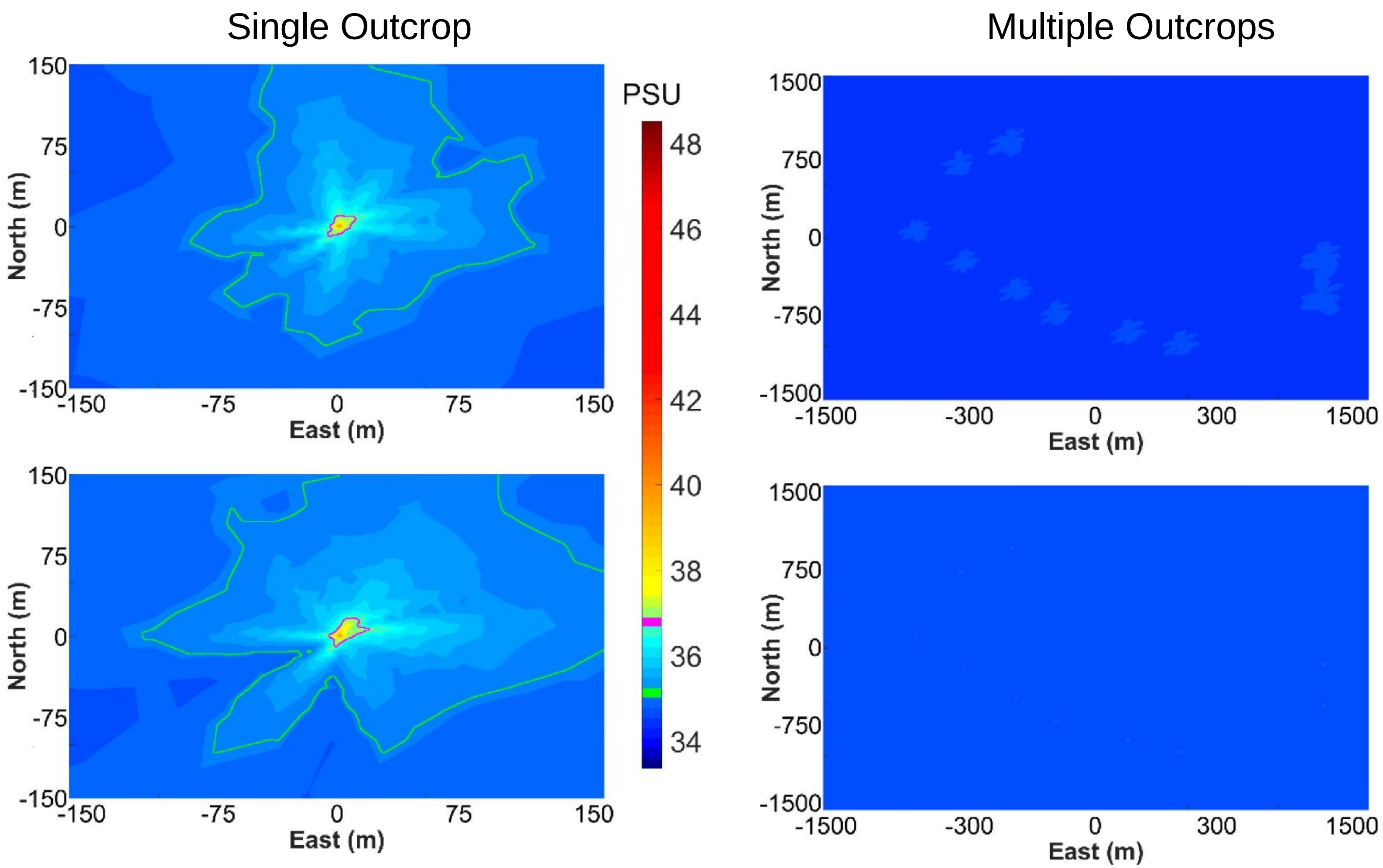
Green: 1:5000 dilution contaminant impact potential

Pink: + 5% PSU salinity potential impact.

24hr Integrated plume footprint

High current

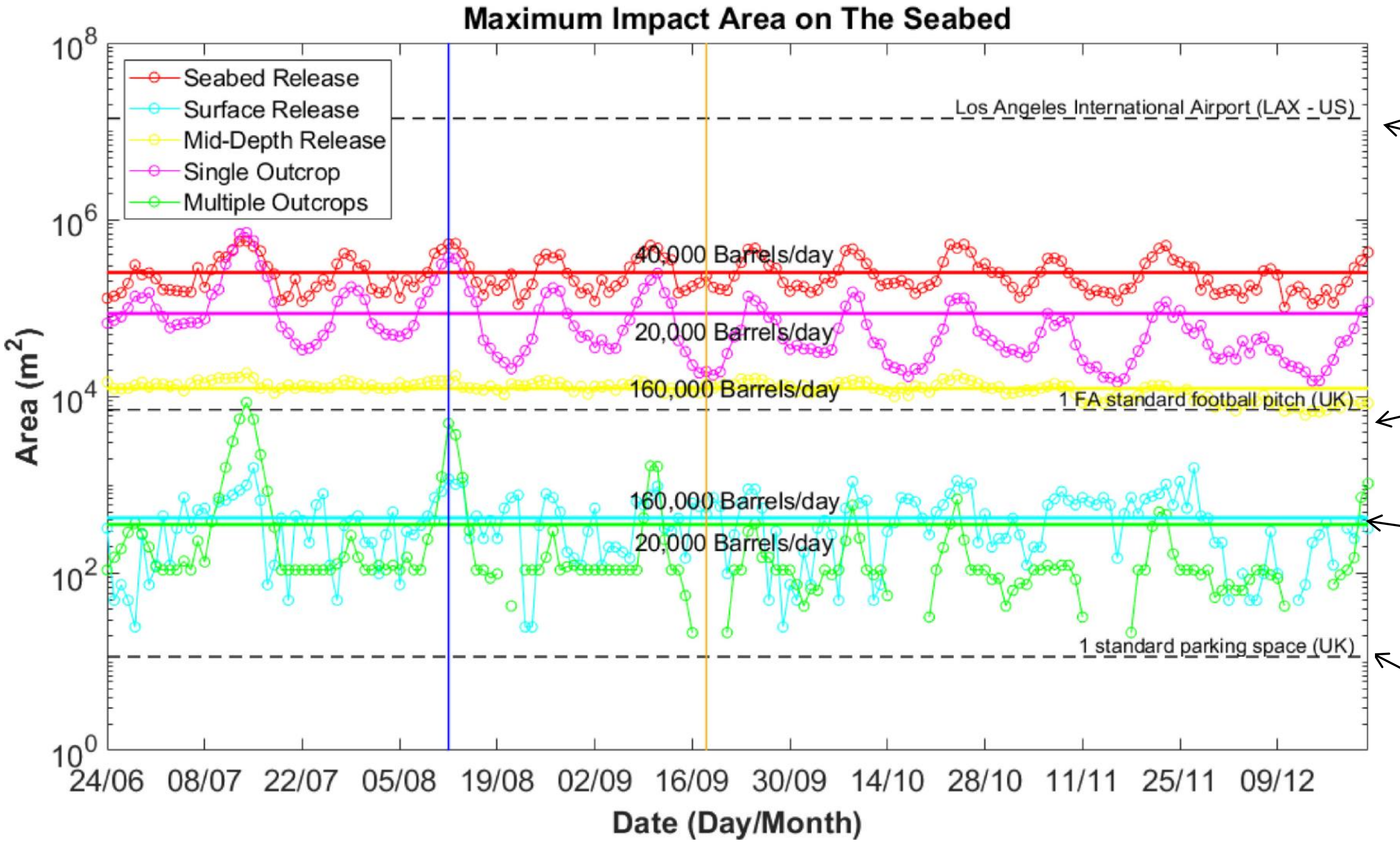
Low current

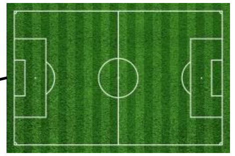


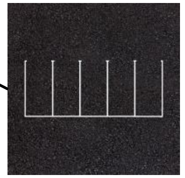
Green: 1:5000 dilution contaminant impact potential

Pink: + 5% PSU salinity potential impact.

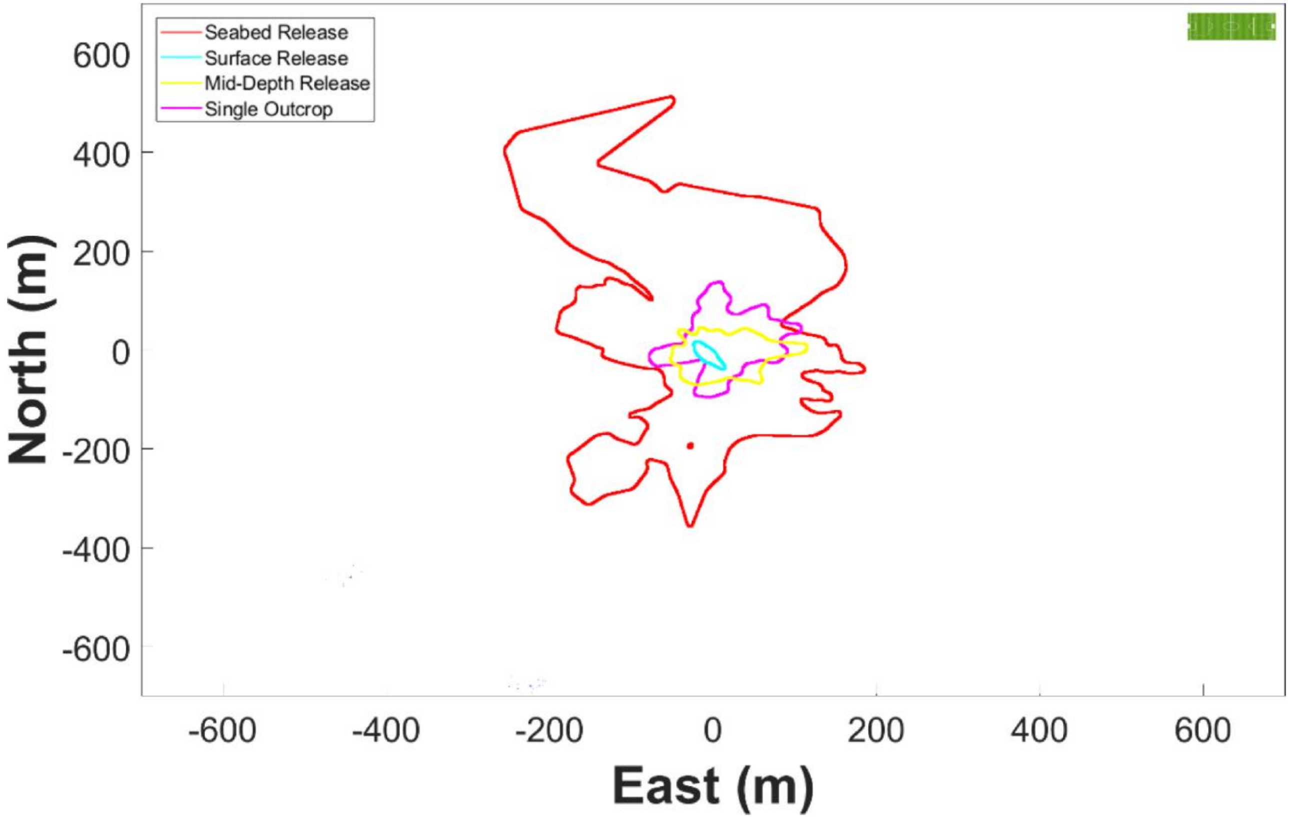
The maximum impacted area on the seabed from every 24 hours over a 6-month period. 1:5000 dilution threshold







1:5000 dilution threshold



Plan view of the salinity plume

The seabed release 40,000 b/d
Outcrop plume 20,000 b/d
Mid depth release 160,000 b/d
Sea surface release 160,000 b/d

The 10 x 2000 b/d seeps aren't large enough to be visualised.

Scenario	Release Rate (barrels/day)	Release mode	Maximum Predicted Impact Area (km²) based on 5000 dilution	Max Salinity (PSU)	Max Temp (° C)
1	40,000	Sea floor	0.3 - 1.57	48.32	11.8
2	160,000	Sea surface	9.3×10^{-4} - 4.25×10^{-3}	48.02	12.2
3	20,000	Sea floor	0.045 - 2.3	44.44	11.0
4	10 x 2,000	Sea floor	0 - 0.027	36.46	9.44

Summary

- In relatively shallow well mixed environments natural mixing processes, dominated by tidal flow, disperse hypersaline plumes rapidly.
- For all the scenarios tested here the impact potential with respect to elevated temperature or hypoxia is highly localised and unlikely to be consequential for the environment. Plumes of elevated salinity are restricted to length scales of 10m-100m for the scenarios tested with no significant accumulation within the sand wave troughs.
- There is a clear affect arising from the mode of release, with disposal at the sea surface leading to far quicker dispersion and smaller seafloor footprints due to dilution in the vertical drop.
- The area impacted is reduced as the number of release points increases.
- Contaminants hypothetically requiring dilutions of order 10^3 pose the largest impact concern.

Summary

Three recommendations follow from this study:

- The mode of release has a significant impact on dispersion. Higher and more numerous release points minimise impact potential.
- Monitoring may be effectively achieved by using standard temperature-salinity sensors deployed on the sea floor, coupled with knowledge of contaminant concentrations. The recommended positioning is at a distance of 5 - 50m laterally from the discharge point, aligned with the dominant tidal axis. Sampling should cover at least one tidal cycle and ideally also sample a spring-neap cycle. Periodic resampling (every few months) is recommended for added assurance.
- Further work addressing different contaminant concentrations, accounting for bio- and sediment accumulation and quantifying long-term impacts may be beneficial.

- **How these details translate to systems such as GOM is an open (but tractable) question!**

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Acknowledgements

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